Bio-productivity of *Pinus sylvestris L.* var. *mongolica* plantation on west Kerqin sandy land

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Abstract   The biomass and net primary production of Mongolian scotch pine (*Pinus sylvestris L.* var. *mongolica*) plantations of west Kerqin sandy land were measured. According to average standard trees, the biomass, net primary production and their distributions of trunk, bark, branch, leaf and root of 16-year-old stand were analyzed. The regressive equation for the estimation of each organ biomass was established through dimensional analysis. Preferable equation with higher precision was selected. The study results showed that the total biomass of the forest community was 62.023 t/hm^2 and net primary production was 5.045 t/(hm^2 · a) , which indicates that the community of plantation possesses high bio-productivity.

Key words: *Pinus sylvestris L.* var. *mongolica*, Biomass, Net primary production, Kerqin sandy land

Introduction

Mongolian scotch pine (*Pinus sylvestris L.* var. *mongolica*) is a fundamental tree species in cold temperate zone, mainly distributed in Heilongjiang Province and Daxing'an Mountain forest region of Inner Mongolia Autonomous Region. With high endurance to cold, drought and poor soil, this tree species has the characteristics of fast growth, short final cutting age and good quality timber, etc.. It has been proven that Mongolian scotch pine is one of the most successfully introduced tree species in semi-arid region after being introduced into 13 provinces and autonomous regions in Northern China.

This study as fundamental work on bio-productivity of the promising species was conducted in west Kerqin sandy land. It was also a preparation for further study on material cycle and energy flow in the ecosystem (Ding 1989). In the meantime, some suggestions on reasonable management of Mongolian scotch pine timber base in semi-arid sandy land were put forward.

Materials and methods

Natural conditions of the study area

The study area is situated in Wulan'aodu region attached to Wongnute Banner, the Inner Mongolia. The climate is semi-arid temperate. Its annual mean temperature is 6.2℃, annual accumulated temperature above 10℃ 3000℃, annual mean precipitation 340 mm, annual evaporation over 2200 mm and frost-free season about 135 d. The vegetation as a transition type between forest and grassland belongs to conjunction of North China flora and Mongolian flora. The existing natural community are only shrubs and grass due to influences of human being and natural factors.

Experimental plot was positioned in even sandy land with a groundwater level of about 1 m. The experimental plantation was pure stand, planted in the spring of 1981 with 2-year-old seedlings and tended in its early age. There was no undergrowth and herbage is few in the stand. Two plots were laid with same size of 10 m × 20 m and same stand age and site condition (see Table 1).

Table 1. Characteristics of sample plots

	Site condition	Stand age /a	Canopy density	Seedling density/m×m	Mean height /m	Mean D.B.H. /cm	Note
Plot 1	Sandy loam, plain	16	0.6	2×3	5.8	10.4	Ditch (3m)
Plot 2	Sandy loam, plain	16	0.7	2×2	5.6	10.0	Ditch (3m)

Methods

Measuring method of tree biomass

Trees in the plots were classified into several diameter grades based on tally. In each grade 1~2 trees with normal trunk and crown and mediate branches were selected as sample standard trees. The sample tree was treated in layer after being cut down. The trunk was cut into several 1-meter-long segments

according to its height. Each segment was weighed and analyzing discs gotten. The verticillate branches were cut separately, some sample branches in each round were picked out and leave-blades and branch were weighed separately. The root was divided into big root, mediate root, fine root and stake after being dug out. Moisture content samples for each organ were taken and dried in 85 ℃ oven to constant weight. After data of dry matter of each organ being collected, regressive equations of organ biomass were fitted and used for calculating bio-productivity of the forest.

Measuring methods of herbage and litter in the stand

There are no underplant under the closed crown after tending. Five 1 m × 1 m quadrates were set in diagonal line in the plots. Fresh weights of aboveground and underground parts of herbage were gotten. Moisture content samples were put in 85 ℃ oven until it reached constant weight. The litter was also collected in the five quadrates and divided into two kinds: unrotted and semi-rotted, and treated in the way mentioned above. Total amounts of herbage and ground litter in the forest were calculated with area as weighted parameters.

Calculating methods of net primary production

Formula 1: $\Delta P_n = G + \Delta L + \Delta A$

Where: ΔP_n is net primary production, G is biomass increment, ΔL is withered matter, ΔA is loss caused by animal (Feng 1982).

According to Satoo (1976), ΔL and ΔA were small

amount to ΔP_n yet difficult to measure. So the formula can be simplified as:

Formula 2: $\Delta P_n = G = G_T + G_B + G_L + G_R$

Where: G is biomass increment, G_T trunk increment, G_B branch increment, G_L leaf increment, G_R root increment.

G can be calculated in two ways: periodic annual increment, average annual increment. Since the plantation was only 16 years old, latter is preferable.

Formula 3: G_T = trunk biomass/stand age
Formula 4: G_{Ba} = bark biomass/stand age

Studies before notes that the ratio of G_T/trunk biomass is a relatively stable index to the same tree and can be used for calculation of other organ's biomass increment.

Formula 5: G_{Br} = branch biomass $\times G_T$ / trunk biomass.

Formula 6: G_R = root biomass $\times G_T$/ trunk biomass.

Mongolian scotch pine is an evergreen tree with 1~4 years old leaves on it in the experimental area. Physiologically, amount of needles is closely related to D.B.H., and the D.B.H. of last year can be gotten through stem analysis. Thus, by using equation of leave weight and D.B.H., G_L can be calculated.

Formula 7: G_L = leave weight at present – leave weight of last year
The equation of the leave weight and D.B.H. is:
Formula 8: $Y = 0.15443 + 0.3710 \times 1.2877X$

$$r = 0.9533^*$$

Table 2. Models for organ biomass of 16-year-old Mongolian scotch pine

Y	x	Type A: $Y = ax^b$			Type B: $Y = a + e^{bx}$			Type C: $Y = a + bx + cx^2$				Type D: $Y = a + bx$		
		a	b	p	a	b	p	a	b	c	p	a	b	p
W_{TK}	$D_{1.3}$	-2.968	2.296	0.929	0.246	0.206	0.944	22.271	-4.481	0.324	0.946			
	$D_{1.3}^2H$	0.775	0.909	0.928	1.651	0.121	0.923	2.714	1.185	0.031	0.932	1.234	1.637	0.921
W_{LF}	$D_{1.3}$	-7.304	3.822	0.913	-1.811	0.329	0.922	25.151	-5.667	0.357	0.921			
	$D_{1.3}^2H$	-1.173	1.546	0.948	0.431	0.194	0.960	1.981	-0.102	0.100	0.957	-2.858	1.356	0.914
W_{PB}	$D_{1.3}$	-7.085	3.823	0.913	-1.555	0.329	0.922	32.494	-7.322	0.462	0.931			
	$D_{1.3}^2H$	-0.917	1.546	0.948	0.607	0.194	0.960	2.559	-0.155	0.130	0.957	-3.694	1.752	0.914
W_{CB}	$D_{1.3}$	-8.674	3.822	0.913	-3.145	0.329	0.922	6.622	-1.492	0.094	0.921			
	$D_{1.3}^2H$	-2.507	1.545	0.948	-0.903	0.194	0.960	0.521	-0.031	0.026	0.957	0.753	0.357	0.914
W_{BH}	$D_{1.3}$	-4.484	2.305	0.939	-1.617	0.207	0.953	3.254	-0.710	0.051	0.956			
	$D_{1.3}^2H$	-1.084	0.911	0.933	-0.204	0.121	0.927	4.400	0.188	0.005	0.936	0.191	0.256	0.920
W_{RT}	$D_{1.3}$	-5.336	3.100	0.927	-0.916	0.272	0.939	22.813	-5.021	0.333	0.938			
	$D_{1.3}^2H$	-0.307	1.241	0.947	0.937	0.160	0.954	1.953	0.349	0.073	0.955	-1.587	1.429	0.914
W_{AG}	$D_{1.3}$	-4.022	3.104	0.926	0.404	0.272	0.939	90.061	-19.673	1.288	0.940			
	$D_{1.3}^2H$	1.015	1.242	0.946	2.259	0.160	0.956	8.191	1.066	0.292	0.956	-5.880	5.358	0.921
W_T	$D_{1.3}$	-3.784	3.103	0.926	0.641	0.272	0.939	112.874	-24.694	1.622	0.939			
	$D_{1.3}^2H$	1.251	1.241	0.946	2.496	0.160	0.955	10.144	1.416	0.365	0.956	-7.467	6.787	0.924

Note: W_{TK}—trunk biomass; W_{LF}—leaf biomass; W_{PB} –perannial branch biomass; W_{CB} –current year branch biomass; W_{BK}—bark biomass; W_{RT}—root biomass; W_{AG}—aboveground biomass; W_T—total biomass.

Results and discussions

Establishment of biomass regressive equation

Dimensional analysis is a commonly used method to calculate biomass of tree organs. There were several kinds of equations being used, such as logarithm, power, polynomial, exponential, linear etc. (Jiang *et al* 1990; Liu *et al* 1994; Mu *et al* 1995). First, correlated matrix analysis was done to biomass and $D_{1.3}$, $D_{1.3}^2$ H of the sample trees. Then equations were fitted by SYSTAT software (Table 2).

By comparing practicability and precision coefficient of the equations, type A and type B were preferable. Following calculations were based on type A.

After the organ biomass of sample plots gotten, the biomass of forest can be calculated by following formula.

Formula 9: $W=W' \cdot C/C' \cdot 1/A$

Where: W is biomass of 1 hm^2 forest, W': is sum of biomass of sample trees, C is basal area of plots, C' is basal area of sample trees, and A is area of plots (hm^2).

Table 3 showed that different organ has different biomass rate to the total tree. The order is: trunk > branch > root > leaf > bark.

Table 3.   Organ biomass of 16-year-old Mongolian scotch pine forest

Iterm	W_{TK}	W_{LF}	W_{BK}	W_{BH}	W_{AG}	W_{RT}	W_T
Biomass /t · hm^{-2}	19.356	10.396	3.091	16.188	48.913	13.016	61.904
W_i / W_{AG} /%	39.6	21.3	6.2	33.1	100		
W_i / W_T /%	31.3	16.8	4.9	26.1	79.0	21.0	100

Community biomass

Although community biomass is defined strictly as dry matter of living plant during a period In fixed area of forest, dry weight of dead part of the community also has significance in comparing bio-productivity of different community. So in this paper, they were surveyed (Table 4).

Table 4. Community biomass of Mongolian scotch pine plantation

Iterm	Tree layer	Field layer	Dead branch on the tree	Litter	Sum
Biaomass /t · hm^{-2}	61.904	0.119	4.310	6.293	72.626
%	85.2	0.2	5.9	8.7	100

In the community of Mongolian scotch pine plantation, tree biomass was 61.904 t/hm^2 and herbage biomass 0.119 t/hm^2, including 0.048 t/hm^2 aboveground part and 0.071 t/hm^2 of underground part. Main Herbs in the community were: *Pennisetum flacidia, Cleistogenes squarrosa, Phragmites communis, Swainsona salsula* and *Glycyrrhiza ularensis*. Amount of ground litter was 6.293 t/hm^2, including 31.6% of unrotted matter and 68.4% of semi-rotted matter.

Net primary production

Net primary production is dry matter production of plant in one year. It's an important index to show community bio-productivity.

Net primary production of 16-year-old Mongolian scotch pine was 5.164 t/(hm^2 · a) in which percentage of tree was 97.7%(Table 5). The order of net primary production of different tree organs is: leaf > trunk > branch > root > bark. According to survey result, the average net primary production of coniferous in the north globe is 5 t/(hm^2 · a) (Lieth *et al* 1977). Young as 16 years old, the plantation, whose fast growing period last to 30~35 years old, had a relatively high bio-productivity.

Table 5.   Net primary production of 16-year-old Mongolian scotch pine plantation community

Iterm	Trunk	Bark	Leaf	Branch	Root	Sum	Herbage sum	Community sum
Net primary production /t· hm^{-2} · a^{-1}	1.210	0.189	1.733	1.102	0.814	5.045	0.119	5.164
Percentage , %	23.4	3.7	33.6	21.3	15.8	97.7	2.3	100

Yield structure analysis

Young as the forest is, differentiation of stand tree occurred. With different growth, the different types of trees should render corresponding tending to accelerate the bio-productivity of the forest.

Trees in the plots were classified into three types: relative dominated, middle, relative dominated in terms of their growth. Representatives were selected and compared (Table 6).

Table 6 indicates that three representatives with different growth had different biomass distribution, which was caused by comprehensive influences of interior and environmental factors. The total biomass increased as the vigor of the tree getting strong as well as the rate of leaf biomass and old branch biomass. The rate of trunk, bark and new branch was on the contrary. The root biomass had little difference among three types.

Table 6. Biomass distribution of differentiated trees Unit: kg

Condition of representative	W_{TK}	W_{BK}	W_{LF}	W_{NB}	W_{OB}	W_{RT}	W_T
$D_{1.3}=13.5$ cm H=6.7m	21.541	3.343	13.929	3.669	17.996	16.087	76.565
Crown diameter: 3.0 m×2.8 m	28.1	4.4	18.2	4.8	23.5	21.0	100
$D_{1.3}=10.4$ cm H=5.4 m	11.954	1.836	5.680	1.496	7.338	7.664	35.968
Crown diameter: 2.0 m×1.8 m	33.2	5.1	15.8	4.2	20.4	21.3	100
$D_{1.3}=7.8$ cm H=5.0 m	7.367	1.148	2.647	0.697	3.419	3.980	19.258
Crown diameter: 1.4 m×1.5 m	38.3	6.0	13.7	3.6	17.8	20.7	100

Note: The value under the line is percentage (%).

Conclusion

Bio-productivity of 16-year-old Mongolian scotch pine plantation on west Kerqin sandy land was measured. Through dimensional analysis method, preferable regressive equation for calculation was selected. The Mongolian scotch pine community of experimental area possessed 62.023 t/hm² of biomass and 5.164 t/(hm² • a) of net primary production. Trees with different growth had different biomass distribution and corresponding tending is needed.

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